The Benefits of an Enhanced Design Methodology applied to Innovative Product Development

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Abstract. The purpose of this study was to model an *enhanced design* methodology applied to the conception of an innovative product in a SME environment. This approach includes C-K theory in a context of disruptive innovation.
In general, the industrial design process consists of four major steps: the *ego-design* phase where the designer conceptualizes a user need, a *techno-design* phase where designer and engineer find solutions to materialize the concept, a *eco-design* phase where social actors involved authorize it and then the *ergo-design* phase where the user adopts the final product. A methodological reflection leads to the modelling of the innovative *enhanced design* reasoning (where major actors are replaced by a bunch of various stakeholders).
The specific SME's case was successful. Using the model, the enhanced design project management was efficient. But some more complex application cases would help secure it.

Keywords: industrial design, innovation, methodology, transdisciplinarity, C-K theory

1 INTRODUCTION

The purpose of this paper is to present the proposition and the field experimentation of a model of an *enhanced design* approach. This approach includes C-K theory applied to the conception of an innovative product in an SME environment. Product or service innovations are vital to the development of most companies, especially in the context of small business industries. This *constrained* environment consists of part of the industrial population with limited resources available i.e. people, finance, and technologies.
According to studies conducted by Findeli, Carbonaro and Quarante on the evolution of design characteristics over time, we can illustrate the following relations as shown on Fig. 1 [Findeli, 2005], [Carbonaro, 2010], [Quarante, 1994].
The Industrial Revolution allowed industry pioneers to provide people with manufactured goods that were obtained far quicker and cheaper than the ones previously created by craftsmen. The major challenge was the ability to industrialize the manufactured goods –in other words, produce with a machine– what was made manually be-

adfa, p. 1, 2011.

fore. That technical issue prevailed above anything else. The shape or form of these products was provided by technical constraints and some references to ancient famous styles. The overall production was very baroque and eclectic. Movements like Morris' Arts and Crafts demonstrated the necessity to give specific shapes to these products. As Findeli explained, an æsthetics era began where designers as form-givers had to conciliate the shape of the product with the technology of the time.

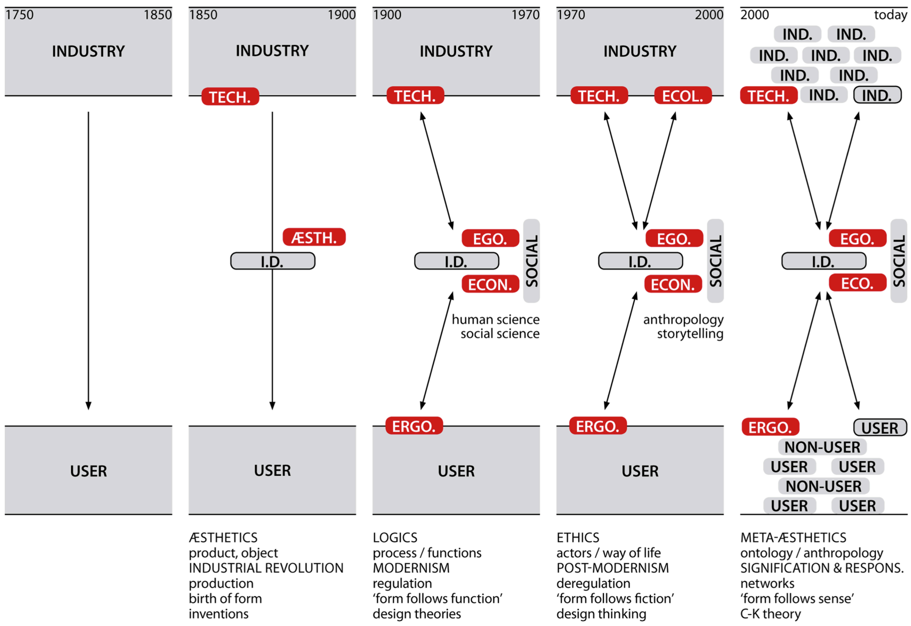

Fig. 1. Industrial Design over time

At the beginning of the 20th century, Designers broaden their propositions. They took into account the first design theories and began to think about processes and functions –'form follows function' as stated some followers of the Bauhaus movement. This logical approach consisted in coming up with a set of rules; a rational attitude about how to make more and more standardized mass-produced objects. Designers had to interact with technology –physical laws and machine potentialities–, with user capabilities –ergonomics, semiotics–, and with a kind of social dimension –mainly economics, hedonism. That Modernism era was characterized by a uniformity of products assigned to satisfy major needs.
In the 1970s, that products' uniformity was quite monotonous. Ettore Sottsass Jr.'s Memphis group contributed to the emergence of the Post-Modern era. It is during this period that Industrial Designers focused on a dramatic deregulation. The Design Thinking experience lead to new ways of need-finding and the imagination of storytelling objects. The latter should have a history, something to share –'form follows fiction'. Designers were more and more involved with the stakeholders and the different experiences surrounding them. The consumer became the focal point. Their indi-

vidual needs, either symbolic or immaterial were converted in products with shorter and shorter life-cycles. This resulted in an attitude of over-consumption, which was called ‘excessivilization’. Confronted with this mindset of excessivilization, Designers, in an ethical perspective, tried to integrate as much as possible the new sustainable way of thinking.

At the turn of the century, the concept of signification and responsibility increased. Designers –like Ezio Manzini– were in search of meaning. They drew on ontology and anthropology as a means of giving more purpose to products –‘form follows sense’. Designers were confronted with customers that were reluctant to shopping, and in search of an authentic and sustainable existence. Their challenge was to create products or services which could bring full and nice human experiences. The business world, both global and wired, was composed of a bunch of networked entities –either on the technical side or in the user one. The Industrial Designer had to look for multiple sources of information and integrate them in his design project.

More than a century ago, Industrial Designers had to use their *techno-design* capabilities and their sensibilities in order to give appropriate shapes to manufactured objects –*ego-design*. A while after, they focused on the user acceptance through ergonomics and human science –*ergo-design*. At the end of the 20th century, sustainable and responsive attitudes towards the environment lead to their *eco-design* approach. Each design project needed the active combination of *ego-design*, *ergo-design*, *eco-design* and *techno-design*.

In general, the design process consists of four major steps as described on Fig. 2. At times, the user needs a product or a service, which they are sometimes unaware of. They could say ‘I need…’ something new, which is the *ergo-design* phase.

Hence, the Designer has to grasp this and conceptualize it in the form of a new concept, very often virtually. In that *ego-design* phase, the designer could say ‘I want…’ and could describe the desired future, something dedicated to the user’s needs.

In the *techno-design* attitude, they could find some technical options able to materialize their new concept. The engineer could provide them with positive answers –‘I can…’

In our social context, the *eco-design* phase is linked to both the economics and the ecology side. All actors involved –social, economic, etc.– could authorize them and then say ‘I regulate…’

Ultimately, in a last movement, the final product is proposed to the end-user for adoption in another *ergo-design* phase.

Those four different steps are not always linear and often unpredictable.

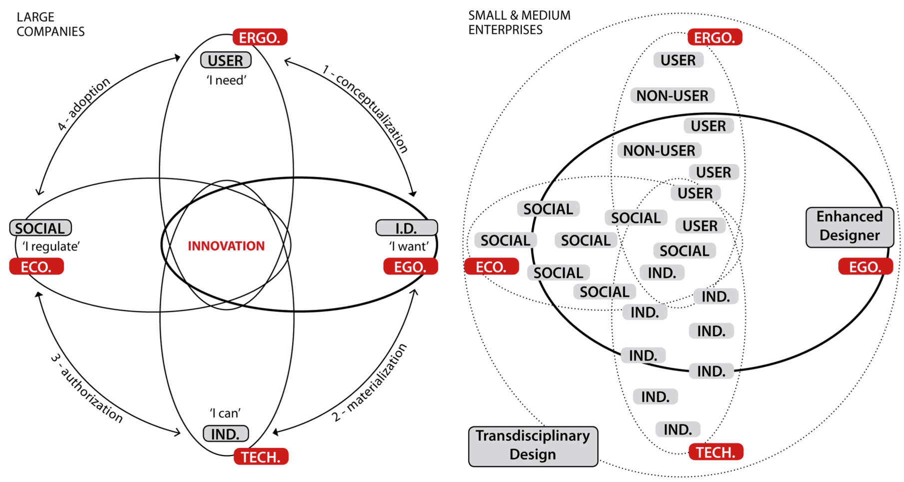

Fig. 2. The Design activity in two business environments

In the case of SMEs, the four actors are not very well identified. Instead of specific teams or people, the latter usually interact with various stakeholders who are mainly outside the core company. A specific team dedicated to user-centered activities could be replaced by multiple personal contacts with individual end-users or even non-users. The same disaggregation occurs in the social and the technical fields.

This is where the notion of the *enhanced designer* comes in. In general, the Industrial Designer has to work closely with technical and marketing teams. However, in an SME context, the aforementioned teams could be reduced to only one part-time person or sometimes nobody. In those situations, the *enhanced designer* has to work with their main client, the stakeholders and the final user. Designers –thanks to their cross-disciplinary skills– are able to deal efficiently with people from those specialties. Even if they do not have the total expertise of the fields, they can easily understand the main values and have the appropriate language. *Enhanced design* should therefore include 1) an artistic dimension: form, harmony, design culture, 2) a social dimension: ethnography, storytelling, ergonomics, ethics, sustainability, 3) a technical dimension: materials, natural and physical laws [Findeli, 2005].

Transdisciplinary design corresponds to the subtle overlapping and synergy of all those fields. In multidisciplinarity, the different specializations are side by side with no cooperation. In crossdisciplinarity, a specialization domain is fertilized by another. In interdisciplinarity, the specialization cooperation is organized by a higher-level concept. Finally, in transdisciplinarity, the coordination is multileveled [Jantsch, 1970]. All the different knowledge from each domain is merged in an extended knowledge base.

The *enhanced designer* has to identify and select members of their team, from the inside or the outside of their company. As non-specialized experts, they have the common language with all those disciplines. The *enhanced designer* is able to ensure the overall work dynamism, synthesis and performance. The designer has to optimize synergy among all the stakeholders with both efficacy and efficiency. They could facilitate shared work by connecting different fields together. The *enhanced designer* is then the best person to coordinate all these fields like a conductor who organizes all the musical contributions or a director who forms his movie team in conjunction with what he imagined his project would be.

Intrinsically, a few scientific papers demonstrate the collaboration of two or three specialisms –but not all of them at the same time– and more specifically in an SME context. The selected issue encompasses the modeling of an *enhanced design* methodology applied to an innovative product development in a constrained environment. Hypothetically speaking, if we provide project leaders with the methodology it would help them enhance the performance of their new developments. It is important to note that the candidate model should be experimented and validated in the field, on a real innovative industrial product design.

Contrary to Scientists, Designers work more in applied research; they take 'use-inspired' principles and they develop applications for them [Driver, 2011]. Designers deal with an increasing numbers of areas. They constantly need to better their trans-disciplinary skills.

In today's globalized world, everything is evolving faster. Innovation is more intense –more and more products are being designed. New solutions are being sought –surprise or breakthrough propositions. Innovation involves group work i.e. moving away from the idea of an inventor working all on his or her own [Garel, 2012]. The need for breakthrough design or disruptive proposition implies finding something very different from the common archetype –also called 'dominant design', the representation anybody has. The collective aspect has a link with the open-innovation. Here people can either have access to new technology not proprietary or can provide their own know-how to others.

2 APPROACH

2.1 Building the first models

A methodological reflection leads to the modeling of this innovative enhanced design activity. Over time, three major means were used to model design reasoning. Initially, researchers talked about 'systematic design' [Agogué, 2013]. Then, designers began to define the 'design thinking' approach [Amaral, 2011]. Finally, the most recent developments of Hatchuel's team deepened the C-K theory as an effective tool for an innovative design [Hatchuel, 2009]. A summary of all the different approaches will be explained below.

Technical design models. At the beginning of the 19th century, the term of engineer appeared. Some tried to analyze their reasoning method used during the development of new industrial products. A first prescriptive approach by Hubka and Eder, improved by the reflections of Pahl and Beitz, lead to the definition of the systematic design mechanisms [Hubka, 1987], [Pahl, 1996]. It consisted of the application of four different phases. For the first one, the project began with the clarification of the task –finding the associate knowledge, framing needs, planning the future actions. The second one corresponded to the conceptual design where candidate concepts merged –exploration of variant propositions, experience of diverse combinations. The third one was the embodiment design where the selected concept took shape –adjusting, materialization, refinement. Then the last one dealt with detail design; the selected solution was clear enough for a transmission to industrialization specialists. The entire process was too often perceived as linear. However, the rigorous separation into different phases helped the management of complex projects and a great variety of industrial products. Later on, Simon took into account the cognitive and human variability of each one involved in the conception's activity [Simon, 1996]. He described the mechanism of reasoning with the analogy of the personal computer –a brain-processor that handled and studied some data-memories as mental representations. Schön insists on the attentive observation of the designer during and after his design [Schön, 1983]. The designer was a hypothesis provider and each of them has to be experimented and evaluated. They have to observe everything surrounding the subject *–what existed–*, to imagine and build mental representations of the problem, then distort them until they obtain a result that makes sense *–what could be done*.

Henceforth, one notices that during the design process the two ends of the process –the problem and the solution– each evolving separately in their respective areas. The designer tries to reframe a wicked problem by creating original mental representations, some specific translations of particular situations or through adventures in real new territories. In this way, they can imagine a 'mental prototype' that is very useful for the understanding of the initial problem. Then, with some loop experiments and some breakdown into sub-problems to solve one by one, their process will lead them to an imagined, tested and validated solution [Cross, 2001]. Gero proposed the FBS model –Function Behavior Structure– that shows the various interactions between a desired space and the real world [Gero, 2004].

To sum up all the different research, Choulier suggests a generic scheme where input and output are well defined; as well as the elementary sub-problem division, each of them had to be solved one by one with iterative loops [Choulier, 2008]. When all the aspects of the initial issues are identified, solved and integrated, a solution to the design issue is given to the industrialization experts.

'Design thinking' models. Initially, Simon could be considered as a pioneer of theorist reflection. Then, the focus is put on collaborative techniques. IDEO did a lot for the emergence, the experimentation and the diffusion of the 'design thinking' approach: books from Kelley and Brown contributed to this [Kelley, 2002], [Brown, 2009]. The process could be described in three different steps. The first one is the 'inspiration' where people had to immerge themselves in the world and give the issue a new formulation. The second one called 'ideation' is where the designer has to be creative and find original solutions. The last one is the 'implementation' where the selected answer has to be put in order and then begin again for another loop cycle [Beckman, 2011].

C-K theory principles. Disruptive innovation occurs when the proposed object is totally different from its 'dominant design' –the way it is commonly perceived; the archetype, the usual answer, the first image going in mind. The innovative designer's challenge is to enhance an actual situation with a tangible new proposition. The gap between today's products and a future solution is rather difficult to cross. There is a kind of genealogy of objects with specific lines; and those lines shaped a common identity reference. That image is quite present in each designer's mind. It is truly important to defix it in order to free the path to new possibilities both about shapes or functions. The short period of time without any tangible reference is a difficult one for design students. Traditional design theories are not so well adapted for disruptive situations –in case of technology breakthroughs for example. They are most efficient when the studied object is quite well identified [Agogué, 2013]. A new design theory should take into account the new identity of disruptive objects. At l'École des Mines de Paris, Hatchuel, Weil and Le Masson defined, experimented and spread the C-K Theory [Hatchuel, 2009]. It is both a design theory and a theory dealing with the mindset used during the conception.

The model is structured in two distinct spaces: the first one –K space– gathers the knowledge and the second one –C space– deals with concepts. In the K space, all propositions have a logic status; people can determine if they are true or false. Whereas in the C space, propositions have no logic status: no one could determine whether they are true or false, they are 'undecidable'. Designing with this theory consists of starting from an initial undecidable root concept –C_0. Then a double expansion, both in C space and in K space, with crossed operators from C to K and K to C, will enrich the root concept C_0 in order to describe it sufficiently for a K validation. All those interactions are drawn in a C-K diagram that shows the reasoning path. The C expansions occur when a K attribute is added to or subtracted from the C_n studied concept.

The model is useful to get rid of strong identity products. Also, the double expansion allows the crossing of concepts and knowledge, which prevent the validation of a good idea but absolutely unrealistic or inapplicable.

Synthesis proposition. To sum up, some notions are very important to keep in mind: co-evolution, immersion, mental prototype, sub-problem division and one by one problem solving, multiple interactions –within and outside the design team.

After the constitution of a project team, the generic process consists of a cycle of different steps. At first, the enhanced designer has to immerge himself in the problem –or situation– context. He or she has to interact with all the different domains listed above –industry and technologies, user experience and social issues. This inspiration phase associated with an attitude of empathy will help him or her form a K base. From the entire gathering, some images are likely to emerge. Many attempts to synthetize or to try some new formulations will help the imagination of a mental prototype. The ideal and desired sketch should orient and drain a flow of ideas to refine and test. The mental prototype could be viewed as the C_0 from the C-K theory. It is a root concept, an undecidable objective but still has a lot of potential and it will attract future propositions –in C space.

The sub-problems division shows the progress of the concept's expansion. The central model place is where all decisions are made. To answer an identified sub-problem, any candidate proposition is analyzed there. According to the team's desired criteria, the test is carried out and a decision follows. If it is validated, then the studied sub-problem is solved and the next one is immediately activated. If the expected characteristics are not met, the proposition is rejected and a new one has to be found for the same sub-problem. If no solution is found, then there is a need to go back to the previous sub-problem division and imagine a new one. Those back and forth movements imply the co-evolution of both the problem and the solution.

These notions were incorporated into an enhanced design process model with a specific symbolic representation. In order to build it, it was confronted *a posteriori* with the reasoning process used for some successful design studies. From that experience, four different activities were identified according to four different axes in the model. The first axis corresponds to *ego-design*, the shape, the personality, and the specific contribution of the designer –as a form giver. The second axis called *ergo-design* deals with ergonomics, usage, functionalities; it concerns the designer's skills –with added marketing and engineering. The third axis takes into account the *eco-design* both economy and ecology. It lists responsive and ethics criteria, with the help of the marketing field. Finally, the fourth axis named *techno-design* refers to engineering, tangible producing and operating aspects, everything relevant to the engineering expertise.

In the representation of that enhanced design process model (Fig. 4), some mini C-K diagrams were used to explain the kind of mental reasoning used during the innovative design process. The diagrams, symbolized by little capsules, showed the respective K space and C space as well as all the interrelations between them. The first capsule named 'needs' represents the immersion phase and the C_0 –or mental prototype– proposition that would drain all future propositions. The central diamond is like a 'processing table' where all the sub-problems and the associate solutions had to be analyzed one by one. The current process *needs, function, behavior, structure, definition* is well integrated [Perrin, 2001]. When all sub-problems are solved, the candidate proposition is validated according to each criterion –or axes–. Then, its definition is sufficient and it can be moved from the C space to the K space, and the product development will go on with the industrialization phase with the engineering team.

2.2 Experimental context

The enhanced design process model had to be tested in a real product development project in order to be confirmed.

SME choice. *TMC Innovation* is a small company of almost twenty people. Its mission is to improve the public area with an appropriate lighting. Faced with cost reduction, some cities turned off the lights in the middle of the night and the sidewalks became unsafe. In that specific case, the company developed a signpost solution instead of the traditional lighting system. A LED strip fixed to the pole, during the production process, uses only 1 W/h, in comparison with a 100 W/h lamp's consumption. *TMC Innovation*'s clients were so enthusiastic about this device that they asked to implement it on already existing poles. There is a high demand for it and the variety of poles' geometry make that adaptation rather difficult. That specific subject was chosen for the enhanced design process model experimentation.

Building the team and results. The project team was lead by a skilled designer well acquainted with that company and the transdisciplinary domains related to the project. The enhanced designer's role was to meet and coordinate the diverse visions about the innovation. The internal team, a technical and marketing one, was often reinforced by external expertise. In an open-innovation perspective, many specialists were associated to the development. For that technical subject, the team management followed a value analysis methodology [Yannou, 2004]. Four major functions and four limited ones were found. Those 8 functions lead to 30 individual solutions. After the validation and combinations, three concepts were chosen for the next step: 'donut', 'lace' and 'stackable objects'. From that last one a new concept 'cordon' emerged. That last one was fully developed until the final product –Uniklic on Fig. 3.

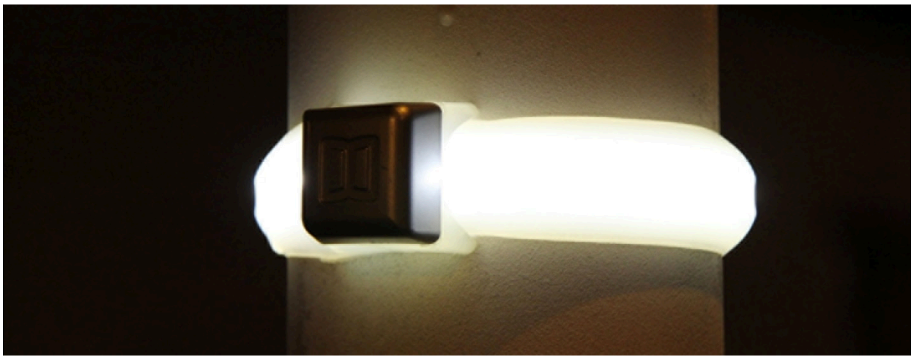

Fig. 3. The Uniklic ring

2.3 Benefits

For the company. The Uniklic product exists; it is a tangible one, is approved by the clients and meets the cost and deadline targets. Some lighting experts were astonished by its technical audacity. For *TMC Innovation* it represents the first milestone towards an innovative new products strategy.

For the modeling. The enhanced design process model is strengthened by a successful real size experiment. The first hypothesis, the interest to model the design process and apply it to an SME context, is reinforced. Thanks to that model, the project management was efficient, both inside and outside the design team. The major steps of that development are shown in the model –Fig. 4. Initially, the C_0 or mental prototype was 'how to fix a LED strip onto a lighting pole'. Secondly, with the value analysis method the problem was framed and divided into many sub-problems to be solved one by one with concepts and candidate solutions. Then, the field validation transferred the Uniklic *cordon* from the C space to the K space. Finally, the specific development resulted in the addition of the new product in the company's catalogue.

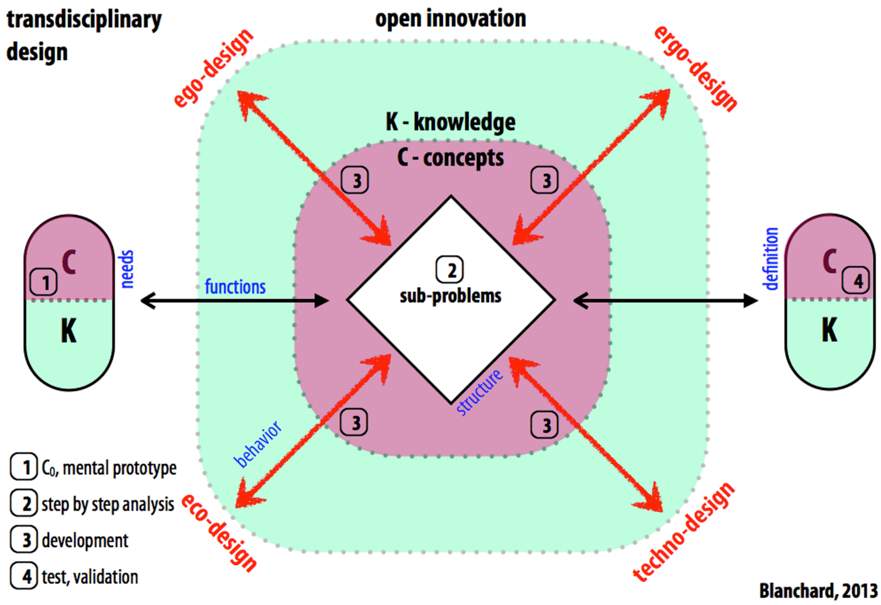

Fig. 4. The enhanced design process in progress

3 CONCLUSION

Often, due to limited resources available, SMEs cannot afford to recruit multi-specialized teams. So, each team member has to be extremely versatile and take into account various aspects of the design development process. From a transdisciplinary perspective, the enhanced designer has to interact with the marketing and technical teams in order to expand the initial industrial design territory. Going back and forth according to the principles of open-innovation would complete these three skills. Using this model would be a success factor. Some more complex and less defined application cases –other than the Uniklic one– would need to be explored. This would help secure the model.

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